

A new subterranean species of *Oncopodura* Carl & Lebedinsky, 1905 (Collembola, Entomobryomorpha, Oncopoduridae) from a cave in Northeastern Iran

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Abstract

A new species of *Oncopodura* (Collembola, Entomobryomorpha, Oncopoduridae) from the Moghan cave in northeastern Iran, built in a carbonate complex of Kopet Dag mountain range, is described. *Oncopodura moghanensis* sp. nov. can be distinguished from other congeners by (1) 6 long subequal lobes in PAO, each subdivided into 3–6 fingers, (2) dens with 7 dorsal feather-like macrosetae; at basal part with 1 dorsoexternal and 2 dorsointernal hooks, at the distal part with 1 dorsoexternal and 3 dorsointernal hooks, (3) distal part of manubrium with long feather like macrosetae reaching middle part of dens, and (4) mucro with 4 teeth, apical tooth very sharp, and 2 scales at its basal half. A table with diagnostic characters of species related to the *Oncopodura moghanensis* sp. nov. and an updated key to the world species of *Oncopodura* are provided.

Keywords

Cave biology, cave fauna, Kopet Dag, Moghan Cave, springtail, subterranean ecosystem

Introduction

Oncopodura Carl & Lebedinsky, 1905 is an eyeless genus of the family Oncopoduridae (Entomobryomorpha) involving both edaphic and subterranean species. Elongated mucro, the presence of scales on the body, thickened sensilla on Ant IV and

the presence of hooks and spines on dens are considered characteristic features of this genus (Yu et al. 2014), which covers 49 species worldwide (Bellinger et al. 2023). Of them, only two species have been recorded from Iran: *Oncopodura ambigua* Christiansen, 1957 and *Oncopodura hamata* Carl & Lebedinsky, 1905 (Mehrafrooz Mayvan et al. 2023).

In terms of biodiversity, Iran is located in the Palearctic biogeographic region and about 54 % of its land area is covered with mountains, including mountain ranges of Zagros, Alborz and Kopet Dag (Azizi Jalilian et al. 2020; Mehrafrooz Mayvan et al. 2015). Karst caves, as the most common type of caves in the world, are the most widespread in the mountainous areas of the country (Juberthie et al. 2001; Ghaderi and Karimi 2014; Malek Hosseini et al. 2015; Malek Hosseini et al. 2016; Moldovan et al. 2018). The present paper is based on the recent speleobiological fieldworks carried out in the Moghan Cave situated in the northeast of Iran in the Kopet Dag mountain range that is formed in massive sedimentary limestones (Manafzadeh et al. 2016; Raziei 2022). Few papers have focused on the subterranean arthropods in Iran, but no studies involving cave Collembola have yet been conducted. This study is aimed at the genus *Oncopodura* Carl & Lebedinsky, 1905, which is highly represented in subterranean habitats with 31 troglobionts altogether (Deharveng and Bedos 2018; Lukić 2019). In this paper, description of a new species of *Oncopodura*, discovered in the Moghan Cave in the Kopet Dag Mountains, northeastern Iran, is provided together with a table summarizing diagnostic characters of world species of *Oncopodura* with PAO with more than 4 lobes and an updated key to the world species of the genus.

Material and methods

Cave descriptions

Moghan Cave takes its name from a village Moghan, it is situated 35 km to southwest of Mashhad, Khorasan-e-Razavi province, on the eastern part of Kopet Dag mountains (36°06'59"N, 59°22'06"E longitude) at altitude of 2193 m above sea level (Fig. 1A, B). The cave has two adjacent entrances located on a relatively steep slope of the mountain with the main entrance 11 m long and 4 m high (Fig. 2A–C). The vegetation in the cave surroundings is very sparse and the entire twilight cave zone (50 m in distance) is completely dry. The cave is about 500 m long, with a maximum depth of 44 m (Fig. 3). It is divided into two floors connected by wells, reaching the height up to 25 m. Moreover, Moghan Cave has five halls, with a water pond located at the end of the fifth hall on the second floor, 5.66 × 6.93 m in area and depth of 30–60 cm (Fig. 2D). The specimens of the new species were collected from the water pool in the deepest part of the cave, which had constant air temperature (12 °C) and relative humidity (RH) of over 73 %, measured with a thermo-hygrometer TFA 30.5015 DTH in December 2023.

Methods

For observation in an optical microscope with phase contrast, initial specimens were mounted in Heinz's medium after clearing in Nesbitt's fluid. To compare effectivity of different clearing methods, additional specimens were boiled softly in evaporation glass dish with 95% ethyl alcohol on electric cooking plate for approximately 1 min to remove fat from the body. For clearing, the specimens were transported to concave glass dish with 10% water solution of KOH for 1 min and then transported to a dish containing chlorophenol until the specimens were transparent. At the end, specimens were mounted on Swann medium. After drying, the cover glasses were ringed with nail polish or Canada balsam to seal the mounting medium. The specimens were observed in Leica DM 2500 light microscope equipped with phase and DIC contrasts, and a drawing arm.

Abbreviations used

Abd – abdominal segment; Ant – antennal segment; PAO – post antennal organ; PS – pseudopore; S – sensillum; Ti – tibiotarsus; VT – ventral tube.

Repositories of investigated material: CoPJSU – Collembola collection of the Department of Zoology, Institute of Biology and Ecology, Faculty of Science, Pavol Jozef Šafárik University, Košice, Slovakia; ZMFUM – Zoology Museum of Ferdowsi University of Mashhad, Mashhad, Iran.

Results

Species description

***Oncopodura moghanensis* Mehrafrooz Mayvan & Kováč, sp. nov.**

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Figs 1–11, Table 1

Diagnosis. PAO with 6 long, subequal lobes, each lobe secondarily divided into 3–6 fingers. Unguis normal, not elongated, untoothed; unguiculus acuminate. Dorsal side of manubrium with 11+11 setae. Dens at basal part with 1 dorsoexternal and 2 dorsointernal hooks, at the distal part with 1 dorsoexternal and 3 dorsointernal hooks. Mucro with 4 teeth.

Type locality. Iran, Razavi Khorasan province, Mashhad city, Moghan village, Moghan Cave, Coordinates: 36°06'59"N, 59°22'06"E, 2193 m a.s.l.

Type material. *Holotype*: female on slide [MoCa101], dark zone, the end part of the cave, 2nd cave floor, collected from water pond surface, 28.ix.2022, temperature = 11.9 °C, RH 73.0%, leg. M. Mehrafrooz. *Paratypes*: 4 specimens on slides [MoCa102, MoCa103, MoCa104, MoCa105], *ibidem*, hand collecting on a stalag-

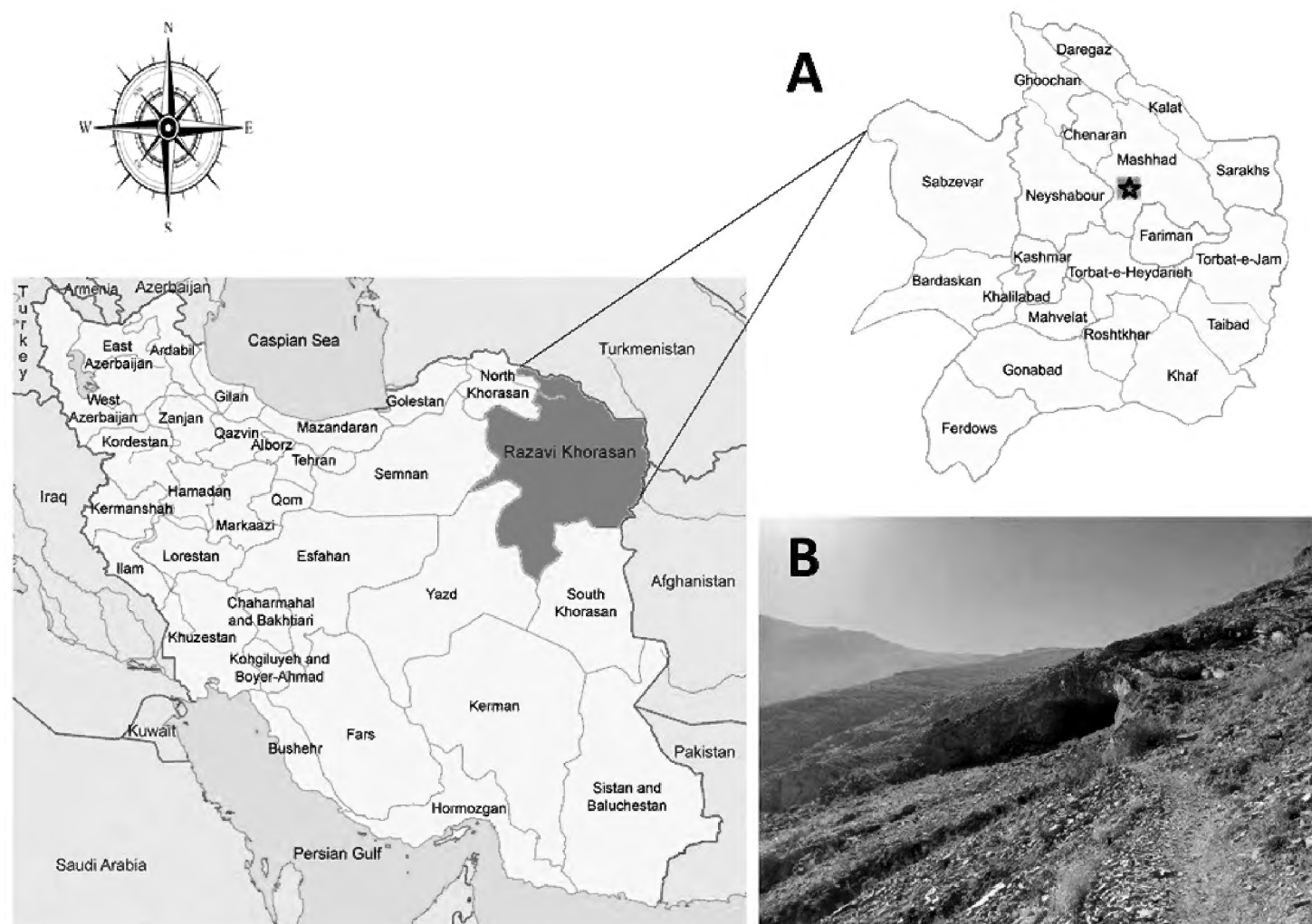


Figure 1. A Razavi Khorasan province in Iran is marked with an orange color; location of the Moghan Cave, where the new *Oncopodura* species was collected, is marked with an asterisk **B** cave entrance and surroundings of Moghan Cave in autumn (Photo: M. Mehrafrooz).

mite, 30.iv.2022, temperature = 12.0 °C, RH 73.4%, leg. M. Mehrafrooz. Holotype and one paratype deposited in UPJŠ; three paratypes deposited in ZMFUM.

Description. Body appearance. Length 1.05 mm on average ($n = 5$, max. length 1.2 mm). Colour white without traces of pigment, body covered by hyaline scales.

Antenna. Antenna nearly as long as head, without apical bulb and scales (Fig. 4A–E). length of Ant I: II: III: IV as 0.02: 0.04: 0.06: 0.08 mm respectively. Ant I with 7 thick dorsal setae and 11 normal setae (smaller than those of Ant II–III). Ant II with 1 broad wrinkled apical sensillum similar to those of Ant III, 1 apical blunt sensillum, 11 dorsal and 6 ventral setae and 4 dorsolateral microsetae. Ant III with sensory organ formed by 2 expanded wrinkled sensilla with 1 blunt, basal sensillum, 8 thick setae at their base, and 10 slender, long setae covered by very soft cilia (Fig. 4B). Ant IV not elongated, with a row of 4 thick and pointed sensilla (Fig. 4C–E), equally distant from each other, and 2 subapical modified setae (Fig. 4D). Ventral side of Ant IV with normal setae, dorsal part with normal and elongated setae.

Head. Eyes absent. PAO well developed and located near base of Ant I, very distinct and large, about 24 μm in diameter, with 6 subequal lobes formed around a central circle, each lobe secondarily divided into 3–6 irregular finger-like lobes (Fig. 5A). Labrum with 4 prelabral setae and 4 rows of 2, 3, 5, 4 setae on papillae (Fig. 6A). Left mandible with 4 teeth and right mandible with 3 teeth.

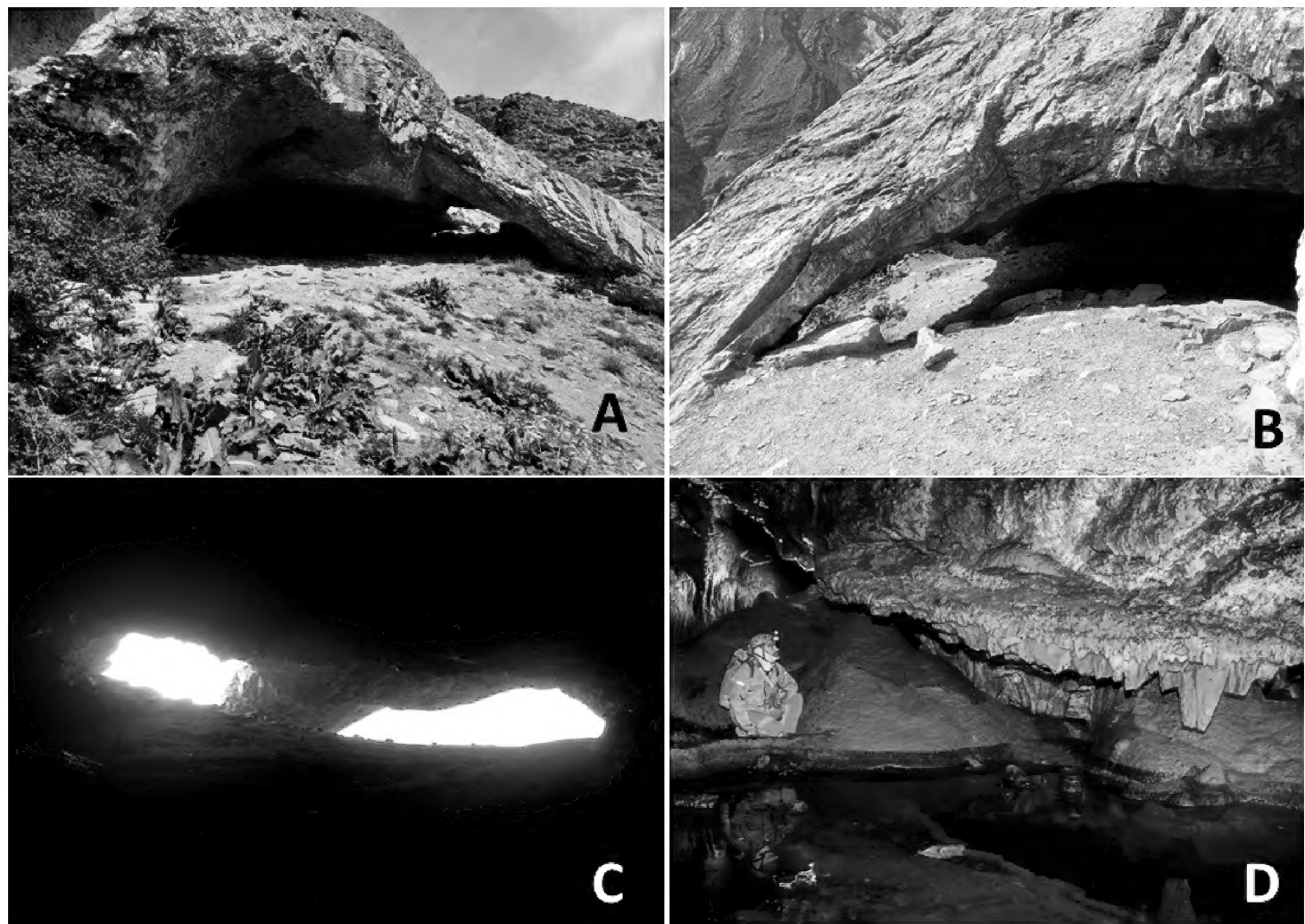


Figure 2. Moghan Cave, northeast Iran **A** main entrance of the cave in spring (Photo: M. Mehrafrooz) **B** second entrance (Photo: M. Mehrafrooz) **C** two cave entrances, view from inside the cave (Photo: M. Mehrafrooz) **D** pool at the end of the cave located on the second floor (Photo: Vahid Ashrafi).

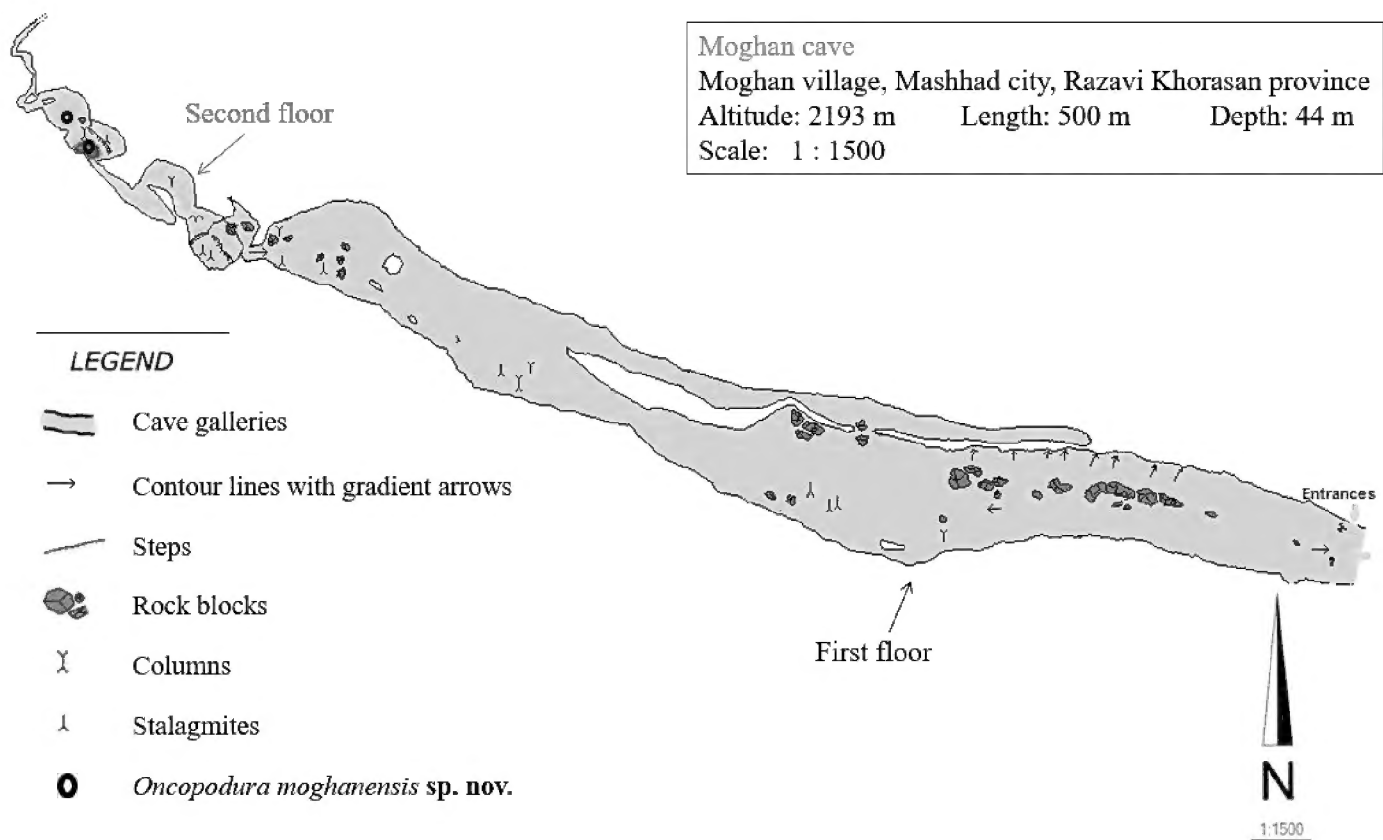


Figure 3. Ground plan of the Moghan Cave (Sketched by V. Ashrafi).

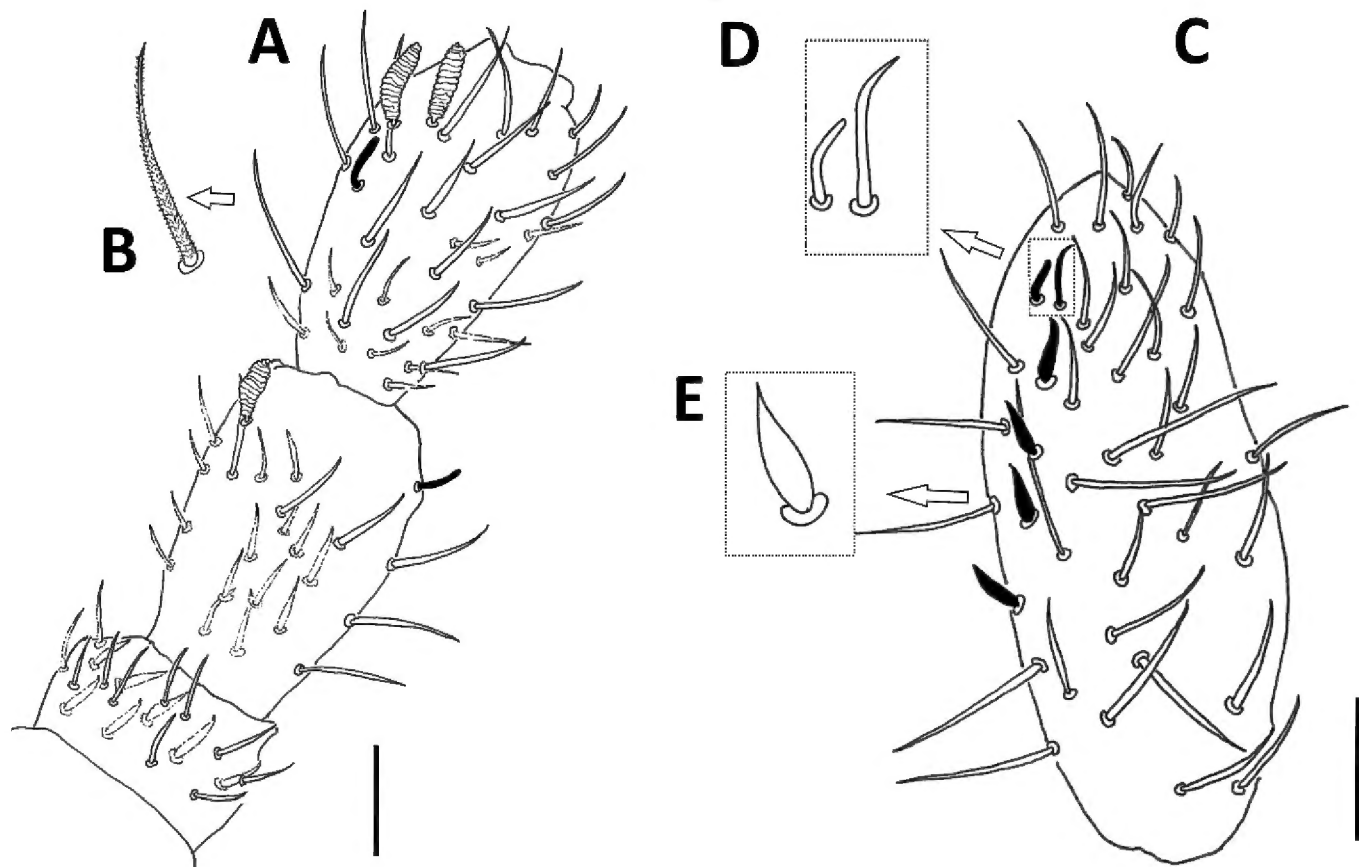


Figure 4. *Oncopodura moghanensis* sp. nov. **A** antennal segments I–III **B** detail of finely ciliated seta **C** antennal segment IV **D** detail of two subapical modified setae near the apical sensillum **E** detail of thick, pointed sensillum. Scale bars: 0.02 mm.

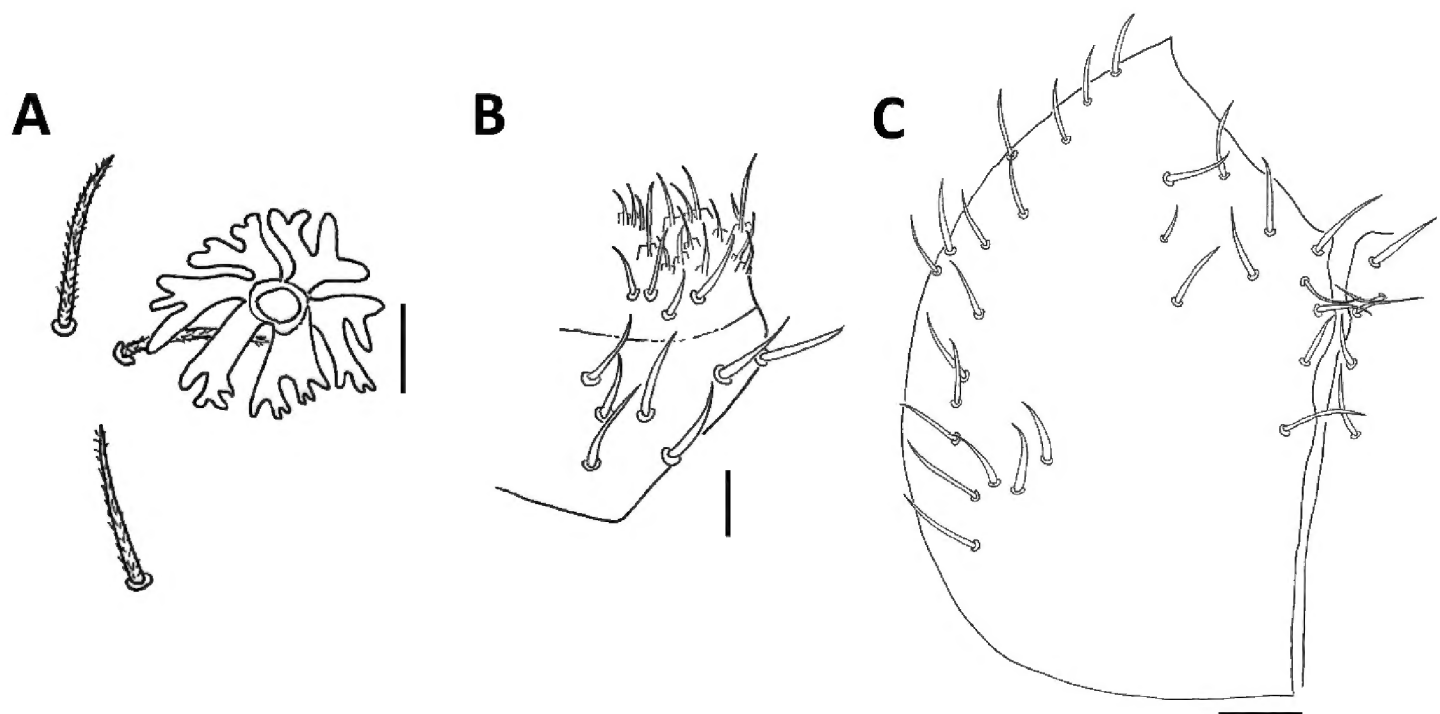


Figure 5. *Oncopodura moghanensis* sp. nov. **A** postantennal organ **B** labium and labial triangle **C** ventral head chaetotaxy. Scale bars: 0.01 mm (**A, B**); 0.02 mm (**C**).

Ventral head without scales, chaetotaxy (setal pattern) as in Fig. 5C, all ventral setae smooth. Head dorsally with 4+4 inter-antennal and 5 lateral macrosetae on each side placed around PAO; 1 short and thick seta posterior to PAO. Two rows of 5 and 6 macrosetae, respectively, in front of prelabral setae. Head with scales, dorsal microsetae as in Fig. 6B. Labial triangle with 7 smooth macrosetae (Fig. 5B).

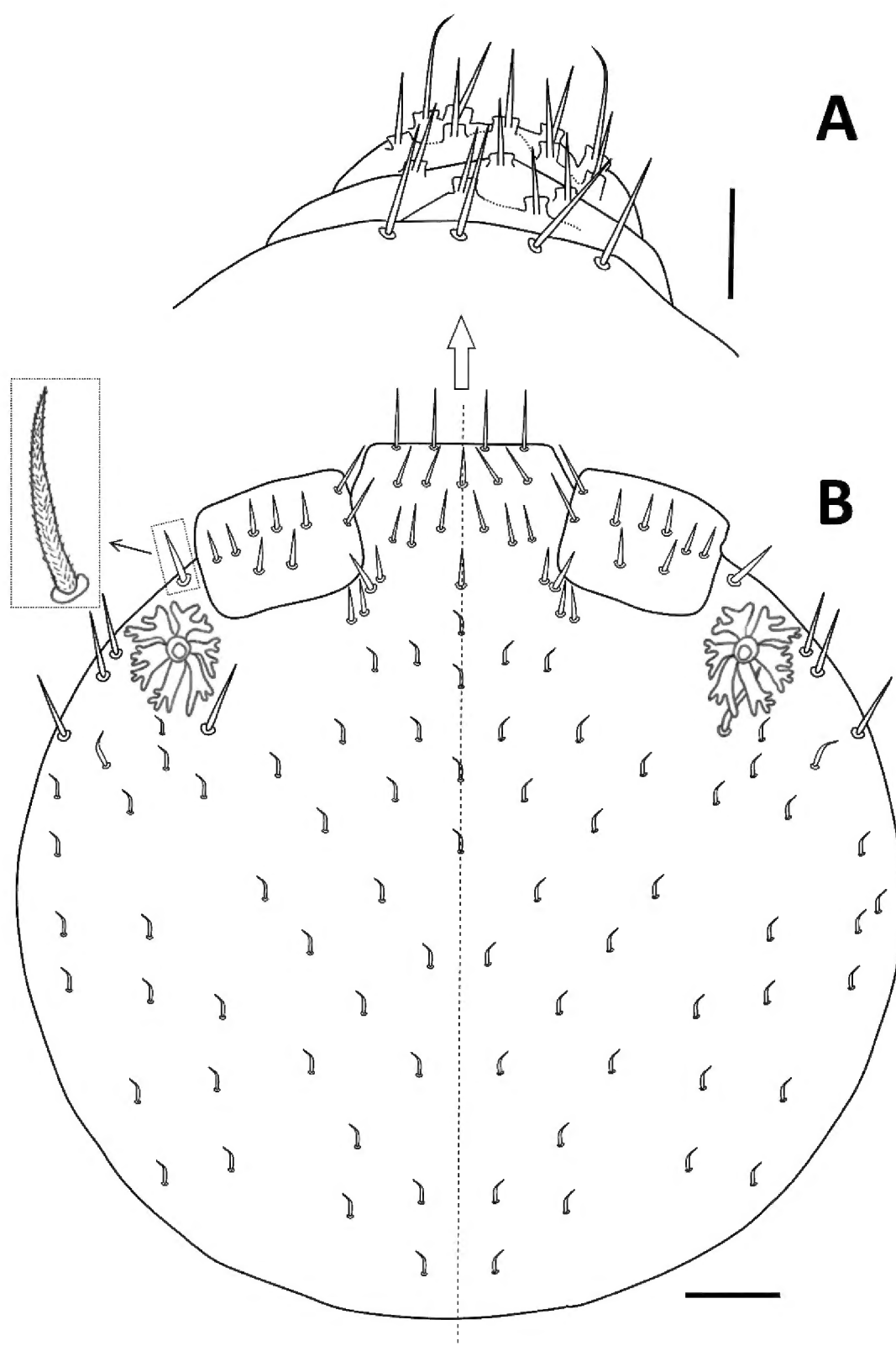


Figure 6. *Oncopodura moghanensis* sp. nov. **A** labrum **B** dorsal head chaetotaxy (dotted circle = inter-antennal macrosetae). Scale bars: 0.01 mm (**A**); 0.02 mm (**B**).

Body chaetotaxy. As in Fig. 7A, B. The chaetotaxy follows the general pattern described for the genus (Szeptycki 1977; Jordana et al. 2012). Mesothorax extended forward slightly over the head, distally with a row of smooth spine-like setae, laterally with 1 ciliated spine-like seta and 1 trichobothrium and 1+1 medial pseudopores. Metathorax with 2+2 trichobothria, 2+2 lateral spine-like setae and 1+1 medial pseudopores. Abdomen I with 1+1 ciliated spine-like setae and 1+1 medial pseudopores, Abd. II with 1+1 lateral smooth spine-like microsetae, medially with 1+1 ciliated spine-like setae, 1+1 trichobothria and 1+1 medial pseudopores, Abd. III laterally with

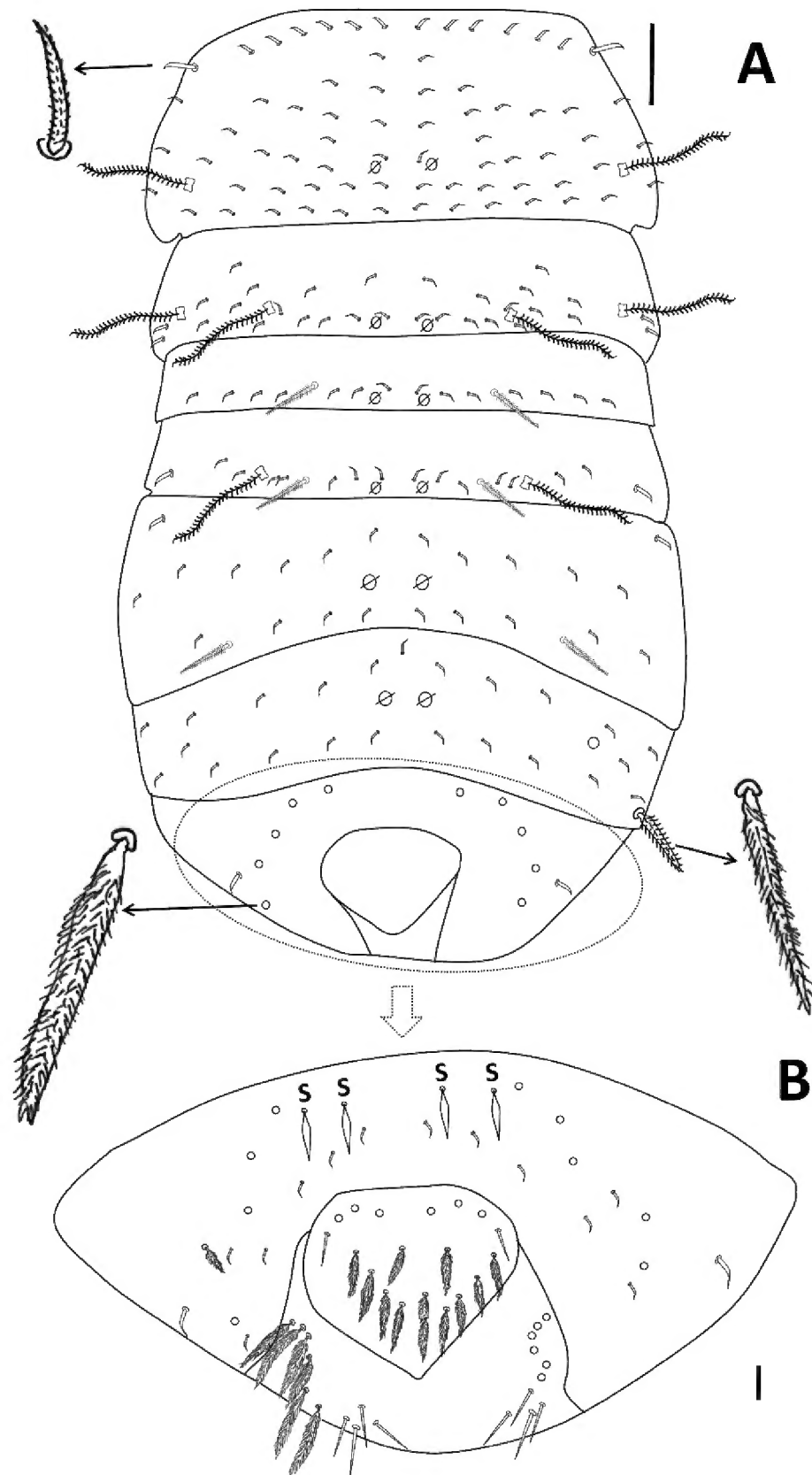


Figure 7. *Oncopodura moghanensis* sp. nov. **A** dorsal chaetotaxy of thorax and abdomen **B** abd V & VI (S = anterior sensilla; circles with a slash represent pseudopores). Scale bars: 0.096 mm (**A**), 0.01 mm (**B**)

1+1 smooth spine-like microsetae, medially with 1+1 ciliated spine-like setae and 1+1 pseudopores. Abd IV with 4+4 ciliated macrosetae and 1+1 pseudopores. Abd V with 2+2 anterior sensilla, 5+5 ciliated macrosetae (shorter than Abd IV macrosetae) and 1+1 smooth spine-like microsetae. Abd VI: epiproct with 9+9 ciliated and 1+1 smooth setae, paraproct with 12 ciliated macrosetae and 8 smooth setae.

Legs. Legs without scales. Chaetotaxy as in Fig. 8A–C. Leg I: trochanter with 6 setae, femur with 3 whorls of 4, 4, 4 setae, respectively; whorl 2 with 1 microseta and whorl 4 with 2 microsetae; Ti with 5 whorls of 4, 4, 5, 4, 7 setae, respectively. Leg II: trochanter with 5 setae, femur with 3 whorls of 4, 3, 5 setae, respectively; whorl 3 with

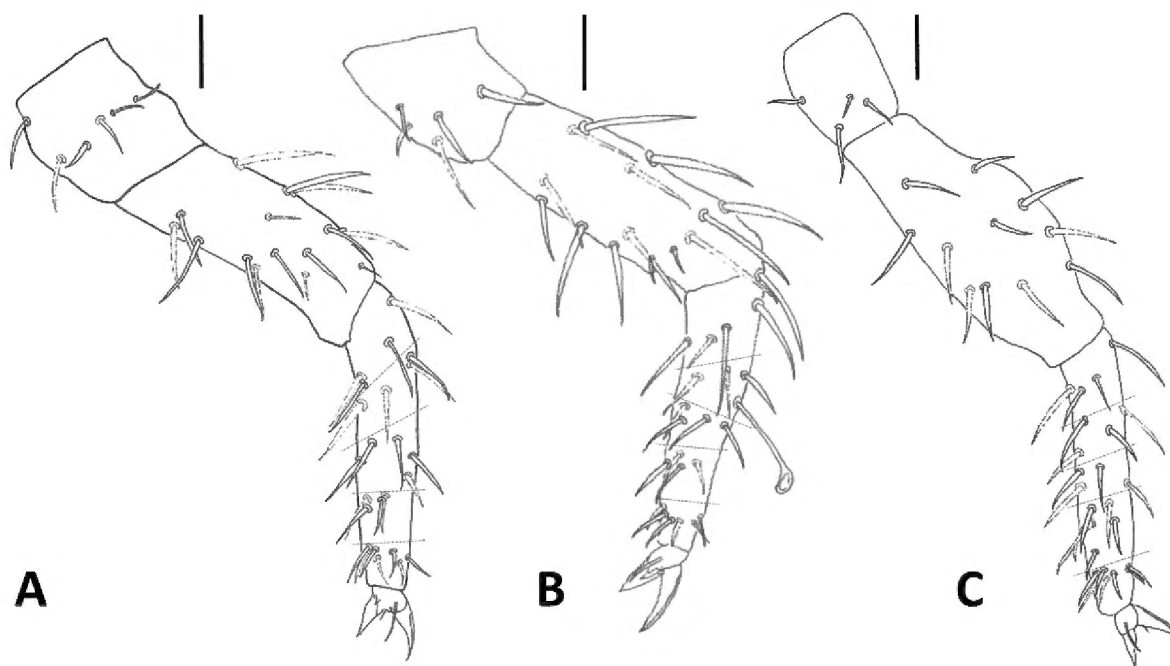


Figure 8. *Oncopodura moghanensis* sp. nov., chaetotaxy of legs **A** leg I **B** leg II **C** leg III. Scale bars: 0.02 mm.

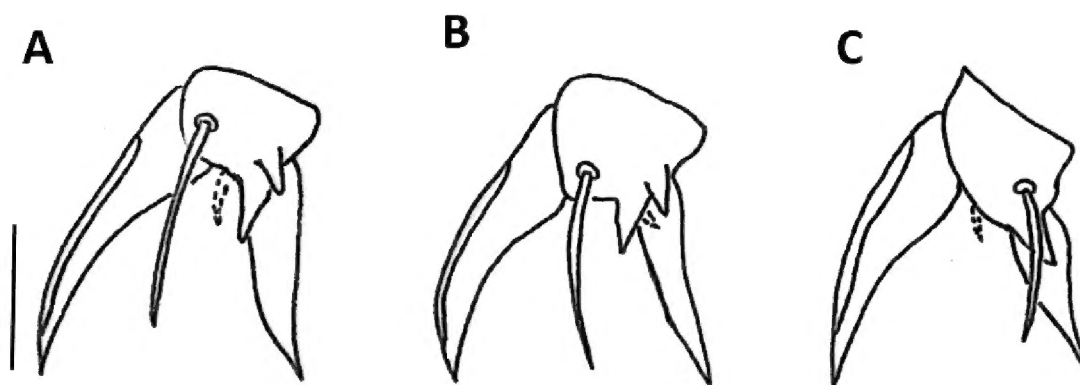


Figure 9. *Oncopodura moghanensis* sp. nov., detail of foot complex **A** leg I **B** leg II **C** leg III. Scale bar: 0.01 mm.

2 microsetae; Ti with 5 whorls of 4, 4, 4, 4 and 6 setae, whorl 2 with 1 stout, clavate (apically expanded) macroseta. Leg III: trochanter with 4 setae, femur with 3 whorls of 3, 3, 5 setae; Ti with 5 whorls of 4, 4, 4, 5, 6 setae respectively, whorl 5 with 1 microseta. Most Ti setae large, acuminate, and extremely finely ciliated; tenent hair slender and acuminate. Unguis (Fig. 9A–C) normal, not elongated, untoothed; inner pretarsal setae long, slightly shorter than the unguiculus, about 1/2 length of internal side of unguis; outer pretarsal setae shorter; unguiculus acuminate.

Ventral tube (collophore) without prominent papillae, with 3+3 setae (2+2 dorso-lateral and 1+1 frontal). Tenaculum with 4+4 teeth, setae absent.

Furca. length of manubrium: dens: mucro as 0.046: 0.040: 0.031 mm respectively. Ventral side of manubrium with scales, dorsal side with 3+3 long and 1+1 short smooth setae, 6+6 ciliated axial macrosetae; 1+1 long, feather-like distal macrosetae reaching half of the dens (Fig. 10A). Ventral side of dens with scales; chaetotaxy of dorsal side of dens subdivided into basal and distal part. Basal part with 2 dorsointernal ciliated hooks, 1 dorsointernal smooth conical spine (broad at the base and strongly tapered at the top), 1 dorsoexternal ciliated hook and 5 dorsal ciliated macrosetae (basal tubercle with 2 ciliated macrosetae, of which inner 1 feather-like and thinner than

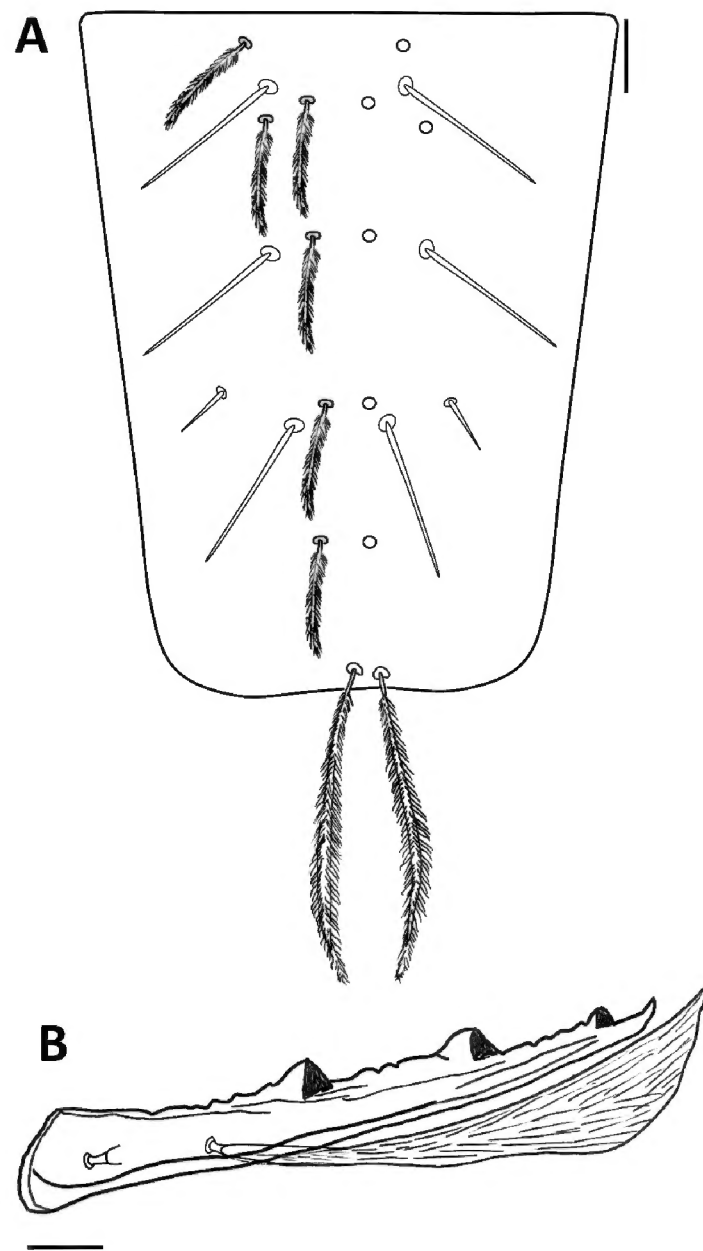


Figure 10. *Oncopodura moghanensis* sp. nov. **A** manubrium dorsal side **B** mucro with basal scale. Scale bars: 0.01 mm.

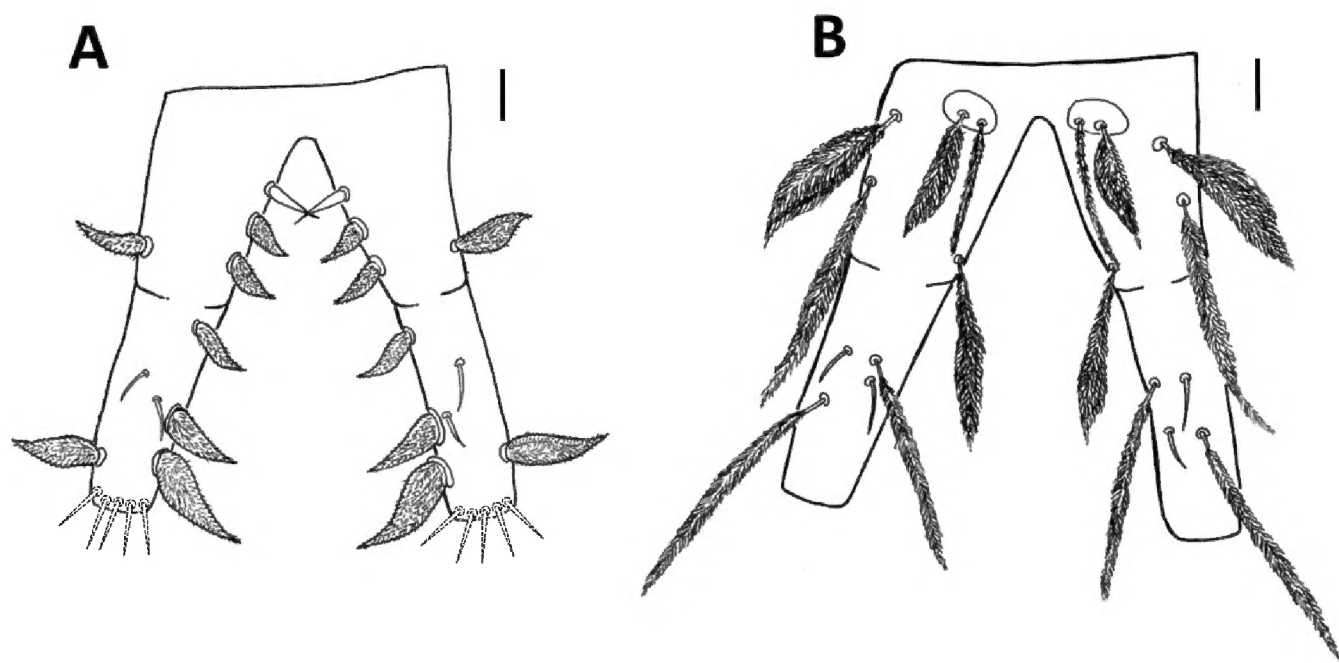


Figure 11. *Oncopodura moghanensis* sp. nov., dorsal side of dens **A** dens with dorsolateral hooks and spines **B** dens with ciliated dorsal macrosetae. Scale bars: 0.01 mm.

outer one). Distal part of dens with 3 dorsointernal ciliated hooks (1 medial, 2 distal), 1 dorsoexternal ciliated hook, 2 dorsal ciliated macrosetae and 2 dorsal short, smooth medial spine-like setae. Dens apically with 5 smooth ventral setae (Fig. 11A, B). Mucro with 4 teeth: 2 apical, 1 medial and 1 basal; 2 scales at its basal half (Fig. 10B).

Table 1. Differential characters of world species of *Oncopodura* with PAO with more than 4 lobes. Characters: **1**, Ant IV medial S number; **2**, Ant IV basal S number; **3**, Ant IV S form, 1 = long, 2 = pointed, 3 = rounded, 4 = short, 5 = trapezoidal; **4**, Ant. III S number; **5**, Ant. II S number; **6**, PAO lobes number; **7**, PAO vesicle fingers number; **8**, Basal dens dorsoexternal hooks number; **9**, Basal dens dorsointernal hooks number; **10**, Basal dens external ciliated macrosetae number; **11**, Basal dens internal ciliated macrosetae number; **12**, Distal dens dorsoexternal hooks number; **13**, Distal dens dorsointernal hooks number; **14**, Distal dens external ciliated macrosetae number; **15**, Distal dens internal ciliated macrosetae number; **16**, Mucro teeth number; **17**, Mucronal basal scales: 0 = absent, 1 = present; **18**, Ungual basal lamella, 0 = absent, 1 = or < ½ unguis, 2 > ½ unguis; **19**, Unguis, 1 = normal, 2 = long. Dif. - number of differential characters in new species *versus* total number of compared characters. * = differences from new species *O. moghanensis* sp. nov. “–” = absence of data; “?” = Insufficient or confusing information in original description; S – sensillum.

Species/Characters	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	Dif.
<i>Oncopodura ambigua</i> Christiansen, 1957	4	1*	3*	0*	0*	6	1*	0*	1*	0*	1*	1	1*	0*	0*	4	1	2?*	1	13/19
<i>Oncopodura atoyacensis</i> Bonet, 1943	4	0	4*	0*	0*	6	1*	0*	1*	0*	2*	1	1*	0*	0*	4	0*	0	1	12/19
<i>Oncopodura crassicornis</i> Shoebbotham, 1911	4	0	3*	0*	0*	6	1*	1	2	0*	1*	1	3	0*	0*	4	1	0	1	8/19
<i>Oncopodura czmur</i> Szeptycki, 1977	4	0	1*	2*	0*	6	1*	0*	3*	2	3	1	2*	1	1	4	1	0	1	7/19
<i>Oncopodura dethieri</i> Janssens & De Bruyn, 2010	4	0	1*	1	0*	6	23-*	0*	3*	–	–	1	4*	–	–	4	0*	0	1	7/15
<i>Oncopodura</i> <i>egerszogensis</i> Loksa, 1961	0*	0	–	1	1	6	3*	1	1*	2	2*	2*	1*	1	1	4	0*	0	2*	8/18
<i>Oncopodura hubbardi</i> Christiansen & Bellinger, 1996	4	1*	1*	2*	2*	56-*	1*	0*	0*	2	1*	1	1*	1	1	4	1	1*	2*	11/19
<i>Oncopodura itatiaiensis</i> Arlé, 1961	4	0	4*	2*	0*	5*	1*	1	2	1*	1*	1	3	2*	2*	4	1	2?*	1	10/19
<i>Oncopodura</i> <i>kuramaensis</i> Yosii, 1956	4	0	4*	1*	1	6	1*	0*	2	1*	3	1	3	0*	1	4	1	–	–	7/18
<i>Oncopodura</i> <i>moghanensis</i> sp. nov.	4	0	2	1	1	6	36-	1	2	2	3	1	3	1	1	4	1	0	1	
<i>Oncopodura pegyi</i> Gruia, 1994	4	0	4*	3*	1	68-*	1*	0*	2	1*	4*	1	3	1	1	4	1	0	2*	8/19
<i>Oncopodura pelissiei</i> Deharveng, 1988	4	0	3*	3*	2*	6	1*	1	2	2	3	1	3	0*	1	4	1	0	2*	6/19
<i>Oncopodura</i> <i>reyersdorfensis</i> Stach, 1936	3*	0	2	0*	0*	6	12-*	0*	1*	1*	2*	1	1	0*	0*	–	0*	0	2*	12/18
<i>Oncopodura tunica</i> Christiansen & Bellinger, 1980	10*	0	2	0*	2*	5*	1*	0*	1*	1*	2*	1	1*	1	1	4	1	1?*	2*	12/19
<i>Oncopodura yosii</i> Szeptycki, 1977	4	0	2	2*	1	6	1*	0*	2	1*	3	1	3	1	1	4	1	0	1	4/19

Etymology. The name of the new species is derived from the Moghan Cave in Kopet Dag Mountains in northeastern Iran, i.e. the locality where the species was discovered.

Taxonomic remarks. So far, 50 species of *Oncopodura* have been described. Based on shape of PAO, *Oncopodura moghanensis* sp. nov. is similar to *O. dethieri* Janssens & De Bruyn, 2010, *O. egerszogensis* Loksa, 1961 and *O. reyersdorfensis* Stach, 1936. The new species is characteristic with 3–6 finger-like lobes in PAO vesicles, while *O. dethieri* has 2–3 fingers, *O. egerszogensis* has 3 fingers and *O. reyersdorfensis* has 1–2 fingers in PAO. Based on dorsal chaetotaxy of dens, *O. moghanensis* sp. nov. is similar to *O. crassicornis* Shoebottom, 1911, *O. pelissiei* Deharveng, 1988 and *O. itatiaiensis* Arlé, 1961. However, Szeptycki (1977) mentioned more complex chaetotaxy of manubrium for *O. crassicornis*, when comparing it with *O. yosii* Szeptycki, 1977. The new species has 6 long and subequal lobes in PAO with each lobe secondarily divided into 3–6 fingers, while *O. crassicornis* and *O. pelissiei* has 6 simple lobes and *O. itatiaiensis* 5 simple lobes in PAO. Among other species, *O. yosii* differs from the new species by 6 simple lobes in PAO, manubrium with numerous dorsal setae (16+16 feather-like setae, 6+6 smooth mesosetae, 1+1 smooth microsetae and 1+1 ciliated macrosetae), and dens without basal external hook.

Deharveng (1988) recognized two basic groups of *Oncopodura* congeners:

1. *O. crassicornis*–group: Ant IV with 4 short and thick sensilla (S-setae) arranged in a curved line, thickened sensilla at the base of segment absent; PAO large with 6 elongated lobes; unguis without large basal lamella (external tooth); pretarsal setae long; dental hooks finely scaly-ciliated, lacking strong denticles.
2. *O. tricuspidata*–group: Ant IV with 4 thick sensilla (S-setae) arranged in a line, and one thickened sensillum at the base of segment (sometimes absent); PAO small, with 3–4 rounded lobes, or they are absent; unguis with large basal lamella, dental hooks smooth, but with strong denticles on their outer surface.

Recently, numerous species have been described with various combinations of the group-specific characters. In many species of *O. crassicornis*–group, Ant IV sensilla are in a line and in some species Ant IV basal sensilla is present, such as in *O. ambigua* Christiansen, 1957 and *O. hubbardi* Christiansen & Bellinger, 1996. Also, PAO in *O. hubbardi*, *O. itatiaiensis* and *O. tunica* Christiansen & Bellinger, 1980 have 5 lobes and in *O. pegyi* Gruia, 1994 has 6–8 lobes. Unguis basal lamella is present in species including *O. ambigua*, *O. hubbardi*, *O. itatiaiensis* and *O. tunica*.

In some species of *O. tricuspidata*–group, ant IV basal sensilla is absent such as *O. cruciata* Bonet, 1943, *O. equatoriana* Thibaud & Najt, 1987, *O. hoffi* Christiansen & Bellinger, 1980, *O. iowae* Christiansen, 1961, *O. mala* Christiansen & Bellinger, 1996, *O. meridionalis* Cassagnau, 1959, *O. puncteola* Yosii, 1956 and *O. subhoffi* Christiansen & Bellinger, 1998. Also, there are some species with 1 single lobe PAO including *O. cavernarum* Stach, 1934, *O. gledensis* Baquero et al., 2007, *O. mala*, *O. siquierae* Seminario-Cordova et al. 2018 and *O. vioreli* Gruia, 1989. On the other, unguis basal lamella is absent in some species including *O. cruciata*, *O. equatoriana*, *O. hoffi*, *O. iowae*,

O. mala, *O. meridionalis*, *O. puncteola* and *O. subhoffi*. Thus, practical use of sorting of *Oncopodura* congeners to *tricuspidata*- and *crassicornis*-group has become questionable.

The new species was collected in the deep cave zone but, nevertheless, it does not show morphological adaptations to subterranean environment such as elongation of unguis or increase in the number of sensilla on antennae and body or augmentation of setae over the head, characteristic for some troglomorphic congeners (e.g. Deharveng 1988).

Key to world species of genus *Oncopodura*

The following key was prepared based on the diagnostic characters of worldwide *Oncopodura* species (adapted from Absolon and Kseneman 1932; Bonet 1943; Szeptycki 1977; Mari Mutt 1984; Christiansen and Bellinger 1998). This should be considered a tentative key, since the limited data on several important characters in some species included.

- 1 PAO absent.....2
- PAO present18
- 2 Ant IV with 4 medial sensilla3
- Ant IV with more than 4 medial sensilla16
- 3 Mucro with two teeth
..... ***O. bidentata* Delamare Deboutteville, 1948 (Ivory coast, soil)***
- Mucro with more than two teeth4
- 4 Mucro with 4 teeth5
- Mucro with more than 4 teeth11
- 5 Dens without basal dorsointernal hooks.....6
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* considered as *species inquirenda*, due to insufficient or doubtful data in an original description.

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